

distributions directly from the data, we modeled the data using distributions with well-studied properties. For our spike counts, Gaussian distributions truncated at zero fit the data well enough to make accurate information estimates, whereas Poisson distributions fit the data substantially less well and lead to poor estimates of transmitted information (Gershon et al., 1998; Wiener & Richmond, 1998). Using the correct distribution is especially important for interpreting the origin of exactly timed spike patterns (see the section below on periodic temporal patterns).

The means and variances of stimulus-elicited responses have been shown to be related (Fig. 1) (Tolhurst et al., 1981a; Tolhurst et al., 1981b; Tolhurst et al., 1983; van Kan et al., 1985; Vogels et al., 1989; Gershon et al., 1998). Gershon et al. (1998) and Wiener and Richmond (1998) showed

that using this relation between mean and variance, and the truncated Gaussian model of response distributions, allows accurate calculation of the stimulus-related information that is carried in the spike count. In general, the amount of information carried in the spike counts of visual system neurons is about 0.4 to 0.5 bits. Thus, two or three independent neurons would be needed to provide the one bit of information that is necessary for dividing a stimulus set in two, and between 6 and 9 neurons to decode which of 8 (3 bits) selected gratings appear.

Rate Variation and Latency

The firing rate generally changes during the response to a single stimulus presentation. Firing responses with the same average firing

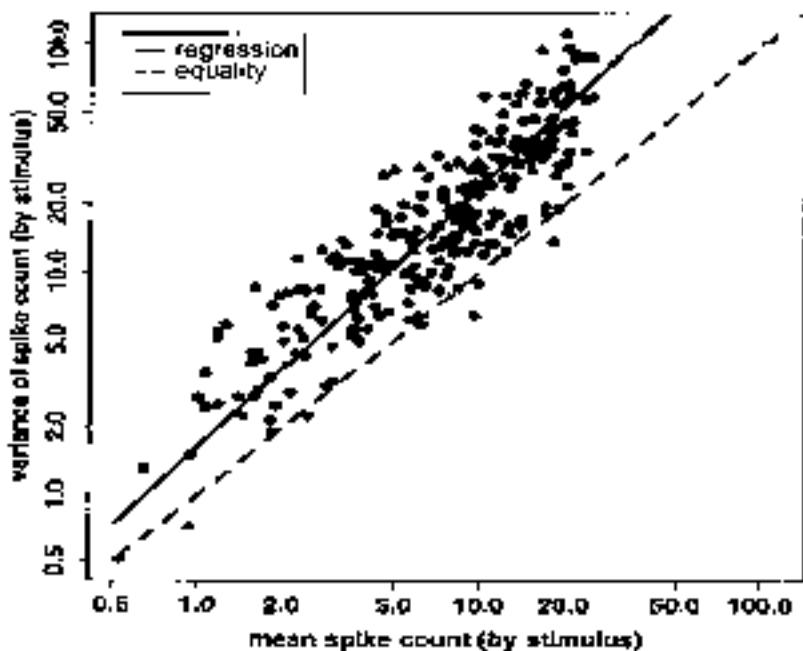


Fig. 1 Relation between mean and variance across all presented stimuli for a single V1 example cell. Each point denotes the mean and variance of spike counts elicited by a single stimulus. The log(variance) is linearly related to the log(mean). The regression line (solid) has a slope of 1.16 and an intercept of 0.5. The data would not be well-approximated by a Poisson process (dotted line). The median variance to mean ratio for these data was 2.4 (interquartile range 1.7–3.1). The variance to mean ratio for a Poisson distribution would be 1.0.